Analyzing the motion of objects in free fall with video

What does the motion of an object in free fall on Earth look like? This question was pondered by great minds such as Aristotle and Galileo. In this lab, you analyze videos that record the motion of falling objects from a set height (5.56 m). This enables us to make a more accurate analysis of *accelerating* objects in the Earth's gravitational field, with and without the effects of air drag.

1. Go to the video playlist in the lab page on Canvas to preview all of the video clips that we'll be analyzing, as if they were made by your lab partners.

2. We are going to analyze each clip to find the *fall time,* t_f , for each object: a heavy ball, a set of keys (twice), and then a crumpled piece of paper. To do this, we first need to learn how to "step" through each clip frame-by-frame, and to establish how many frames per second the video is played at. Proceed as follows.

Establishing the video frame rate "FPS" for timing:

Watch the first clip (on Canvas) of the red ball being dropped.

a. Go to the settings (gear wheel icon) below the video and select the highest quality (720p60 if available).

b. Let the clip play, but Pause it between 1 and 2 seconds. You can also slow down the video speed in Settings to make this easier.

c. Use the period "." key repeatedly to advance frame by frame, until the "seconds" timer below the video on the left changes from 0:01/0:03 to 0:02/0:03. You can also use the comma "," key to step backwards, if needed.

d. Now start counting "." key presses as you advance the video frame-by-frame until the counter changes by 1 second to 0:03/0:03. This will tell you the "FPS", the number of frames per second. Record the value above the data table on the next page. (This number is usually 60, but is sometimes 30 if you have a slower internet connection.)

If you have a stable internet connection and always choose the highest Quality (720p60 under Settings, gear icon) for playing all the video clips, this FPS value should be the same for all of them. (To verify, you can quickly perform the procedure in parts (a) through (d) for each clip before analyzing the falling objects in them. Also, each object takes about 0.9-2.0 seconds to fall, so if you get something very different, your FPS is probably wrong.)

The four video clips can be viewed separately on the lab page on Canvas. Note: do not share these videos of other students (or frames from these videos) with the outside world! Remember to select the same Quality for each video (under Settings – gear icon) before playing each one.

The videos are: Red ball, Keys (sideways)m, Keys (vertical), and Crumpled paper.

To help answer question 8, in addition to the pre-lab videos provided, play with the online simulation comparing Earth and Moon gravity drops at
https://go-lab.gw.utwente.nl/production/gravityDrop/build/gravityDrop.html?preview

As always, do your own work, then create a merged PDF of your analysis results (page 2 only) for the online submission.

Grossmont College Gravity Laboratory. NAME: ____________________ DATE:_______________

1. Watch the video clips again, using the slider, period or comma keys, or slow motion video control (in Settings, the gear icon) to follow each object falling in slow motion. What are some similarities and differences between the motions of the ball, keys, and the paper object?

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2. For each object (first the "dense" ones, then the paper), use the period and comma keys to count how many frames between the moment the object was dropped (NOT the start of the video!) and the instant when it hit the ground.

3. To find the duration t_f *of* the object's fall, take that number of frames between releasing the object and impact, then divide by the frame rate (FPS). **Show one example of this calculation in your lab notebook, in detail with units!**

4. Remember from our first lab that the average speed v_{av} = (total distance covered) divided by (time taken). The total distance fallen from the balcony rail to ground is H =5.60 m. Calculate v_{av} for each object in your lab notebook and show your results in the table below. Use 3 significant figures for all values reported in the table.

5. **For the dense objects only:** For a constant acceleration from 0 m/s, you can use the average speed to find the final (impact) speed $v_f = 2v_{av}$. This comes from the definition of the average of zero and the final speed, i.e. $v_{av} = ½ (0+ v_f)$

6. Now you have the impact speed, find the acceleration g (= change in speed / time taken) = v_f/ t_f. (Since the crumpled paper floats down at ~ constant speed, this calculation is not applicable to it.)

***Drop height H* = 5.60m. Video frame rate FPS = __________ frame/s.**

Clip #	Object	# frames from release to impact	Fall time t_f (s)	Average speed $v_{av} = H / t_f$ (m/s)	Impact Speed $v_f = 2v_{av}$ (m/s)	Acceleration $g = v_f/ t_f$ (m/s^2)
1D	Ball					
2D	Keys					
3D	Keys					
3P	Paper				*Not applicable*	*Not applicable*

6. From your 3 trials for the dense objects only, calculate the average value of g ± its uncertainty. (Recall that in these labs, we use uncertainty =½ (max. value – min value). g = ___________ ± ___________ m/s/s.

7. Briefly comment on any difference between your results and the accepted value of g for Earth, 9.8 m/s/s:

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8. Finally, describe in as much detail as you can, how the motions of each object would be different from what you observed above, if you performed this experiment outside on the surface of the Moon. For guidance, in addition to the pre-lab videos provided, play with the online simulation provided at the bottom of page 1.
